3.3.2 Boundary Regions

Seasonal variation for the Northwest States (HMR No. 43) is given for the months October through June. A separate variation was determined for each of four zones, three of which border our study region. Elevation plays a part in differentiating among the zones.

By analysis of station maximum observation-day precipitation of record, the seasonal variations for the three zones were smoothly extended through the remaining 3 months. Percent of the August values for each month are shown in table 3.3.

Table 3.3.--Seasonal variation east of Cascade Ridge in Northwest States as percent of August

Zone in HMR No. 43	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	91	91	95	87	74	67	84	100	107	108	107	104
C (5000 ft) (1524 m)	92	92	91	94	98	97	98	100	100	100	99	96
D	90	90	90	95	100	100	100	100	100	98	97	94

The seasonal variations of HMR No. 43 stress winter maximum values west of the Cascade Ridge and in a region to the east of the ridges (Zone B). May through October are the maximum months near the eastern borders of the Columbia River drainage (Zone D). Between these is a transition zone with a maximum from late summer to early winter; the importance of winter maximum increasing with elevation in zone C.

From HMR No. 36, the seasonal variation for the west slopes of the Sierras is adopted for use at the western border of the Southwest Region. Again it was necessary to extend the seasonal variation given there throughout the year or over the months of May through September. Maximum observation-day precipitation amounts for high elevation orographic stations were used for this extension. The results in percent of August are shown in table 3.4.

Table 3.4.--Seasonal variation in Pacific drainage of California as percent of August

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
106	106	102	97	91	91	96	100	103	104	104	105

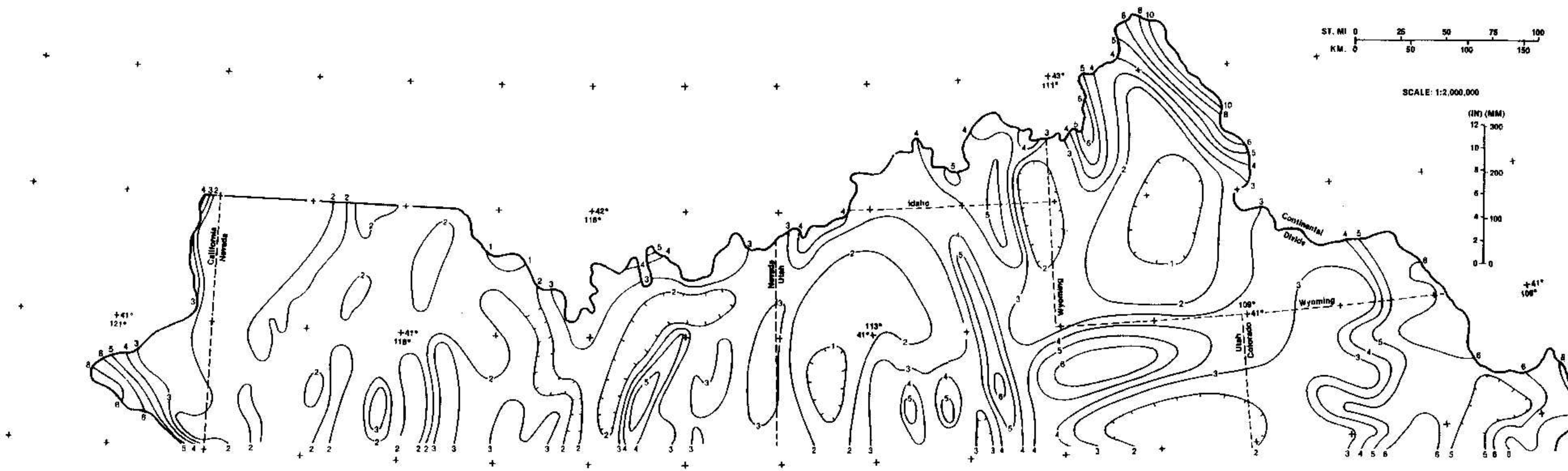


FIGURE 3.11a (Revised) — 10-mi² (26-km²) 24-hr orographic PMP index map (inches), northern sectio

FIGURE 3.11b (Revised) — 10-mi² (26-km²) 24-hr orographic PMP index map (inches), north-central section.

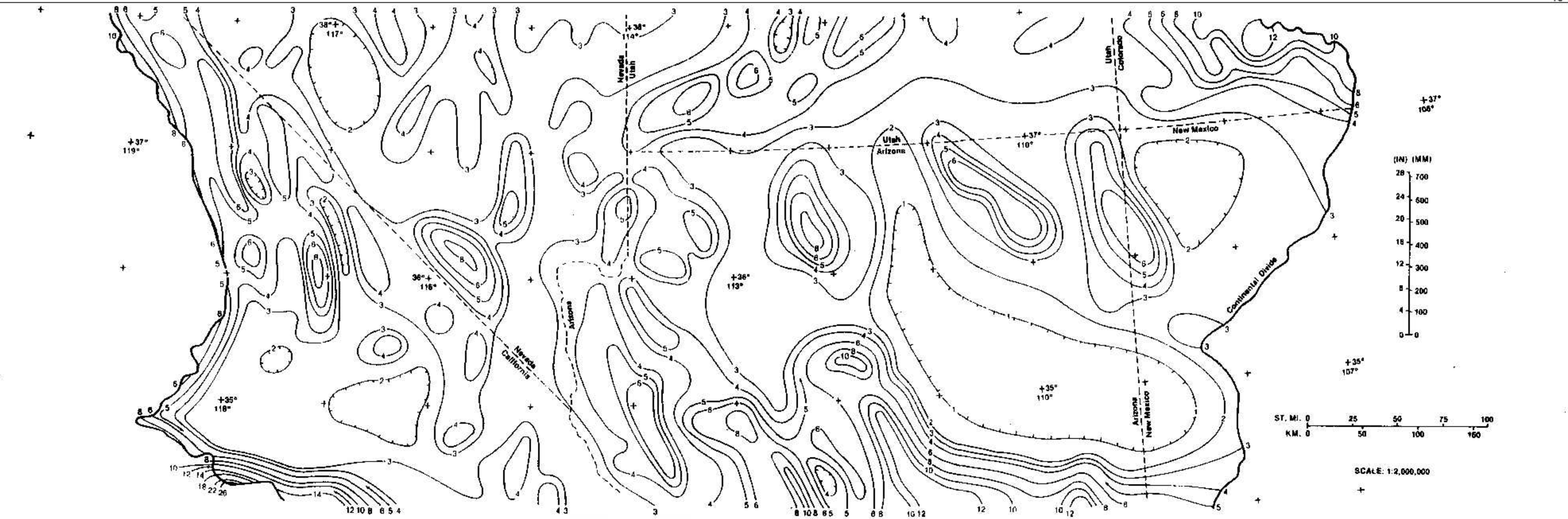


FIGURE 3.11c (Revised) — 10-mi² (26-km²) 24-hr orographic PMP index map (inches), south-central section.

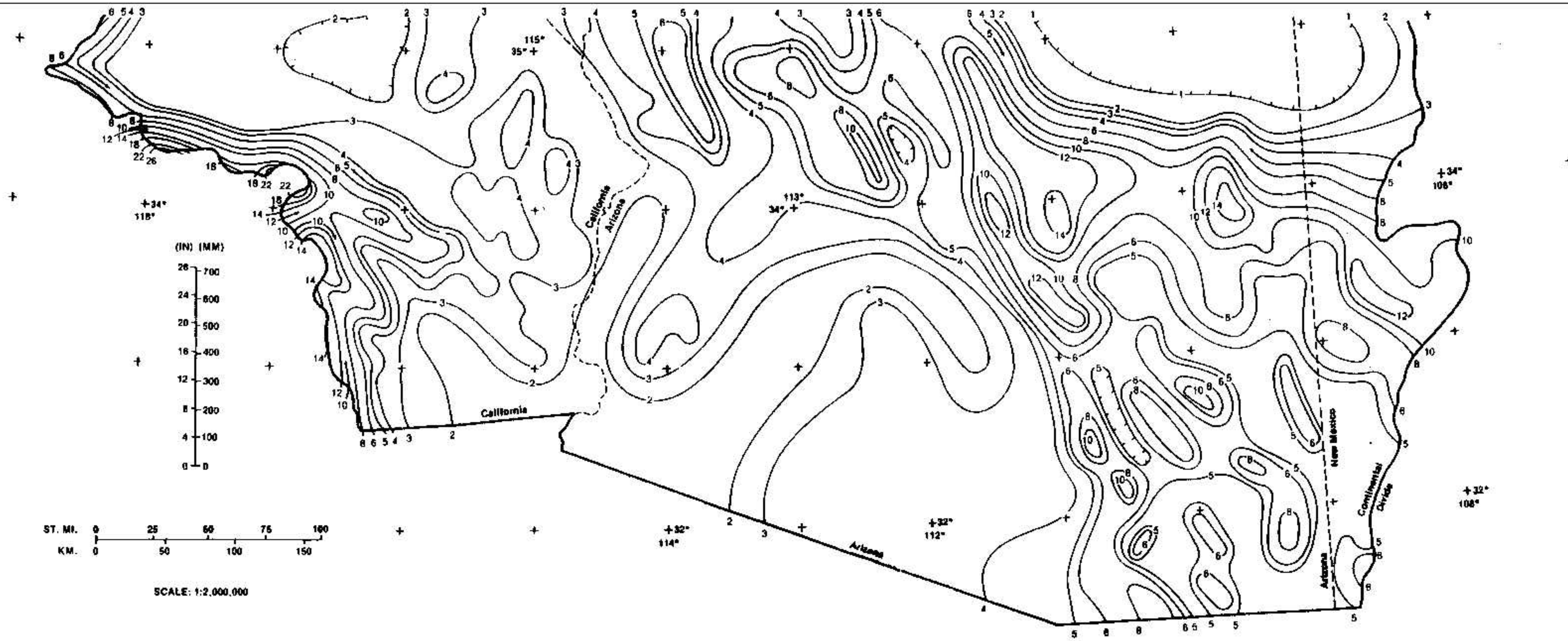


FIGURE 3.11d (Revised) — 10-mi² (26-km²) 24-hr orographic PMP index map (inches), southern section.

3.3.3 Indices Within the Region

3.3.3.1 Maximum Precipitation at High Elevations. On the mountain slopes north and east of Phoenix, Ariz. the maximum observation-day rainfalls of record for seven stations for each month of record were averaged. Highest average values were equal for August and September. Lowest values (61% of highest) were in May. Use of these data as an index to seasonal variation of orographic precipitation assumes either that the precipitation is entirely orographic or that the seasonal variation is the same as that for convergence precipitation. Probably these stations come closer to being an index to orographic variation than any other stations in the Southwestern States where the terrain is more broken and complex. It would also assume no regional variation in the pattern of seasonal variation.

The seasonal variation of maximum observation-day precipitation (by month) was further evaluated at high-elevation stations at various locations in the Southwest States. In northern Nevada, a seasonal plot of the data showed a fall maximum with relatively little variation through the winter. In southwestern Wyoming and extreme northeastern Utah, spring maximums predominate with a secondary maximum in early fall. Stations in Colorado north of about 39° N indicate a broad summertime maximum extending from June through September. These data, when averaged, gave an estimate of seasonal variation near the center of the region (the northern border of Arizona.) July, August, and September gave about equally high values. The lowest values, in May and June, averaged 80% of summer.

3.3.3.2 Maximum Winds and Moisture. A physical index of intensity of orographic precipitation at a given location is the product of the strength of the horizontal wind normal to the mountain and the moisture content of the air column. This index was evaluated seasonally from upper-air observations at Tucson, Ariz.

From the twice-a-day observations (1956-69) a series of maximum southerly wind components were determined for each month for the 900-, 700-, 500-, and 300-mb (90-, 70-, 50-, and 30-kPa) levels. The 0.01 probability southerly components were then computed using the log-normal distribution. These monthly wind components were then expressed in percent of the highest value of the 12 months for each level.

Precipitable water through the 300 mb level associated with the maximum 12-hr persisting 1000-mb (100-kPa) dew points assuming a saturated pseudo-adiabatic atmosphere for each month at Tucson were also expressed in percent of the highest value. Multiplication of the percentages of wind and moisture for each month gives an index to the magnitude of moisture transport. The highest value of this index was about the same for August through October. December through May averaged 78%.

3.3.3.3 Orographic Model Computations. The detailed orographic precipitation computation model described in HMR Nos. 43 and 36 was applied to 10 profiles in a steep upslope region. Five of these were north-south slopes north of Phoenix; the others were SW-NE slopes near the same location. Input to the model were maximum winds at Tucson described previously and moisture based on maximum 12-hr persisting 1000-mb (100-kPa) dew points. The computed precipitation for the 10 slopes was used as another seasonal index to orographic PMP. September gave the highest orographic precipitation of the 12 months followed by October (92% of September) and July (81%). December and January were the months of lowest values (68% of September).

3.3.4 Smoothed Maps

Recommended seasonal variation of orographic PMP is provided by mid-month maps, figures 3.12 to 3.17, showing isolines of percent of the orographic index. The several different indices discussed were used as guidance in these analyses. The maps have been adjusted to yield smooth seasonal curves at grid points covering the region.

3.3.5 Supporting Evidence

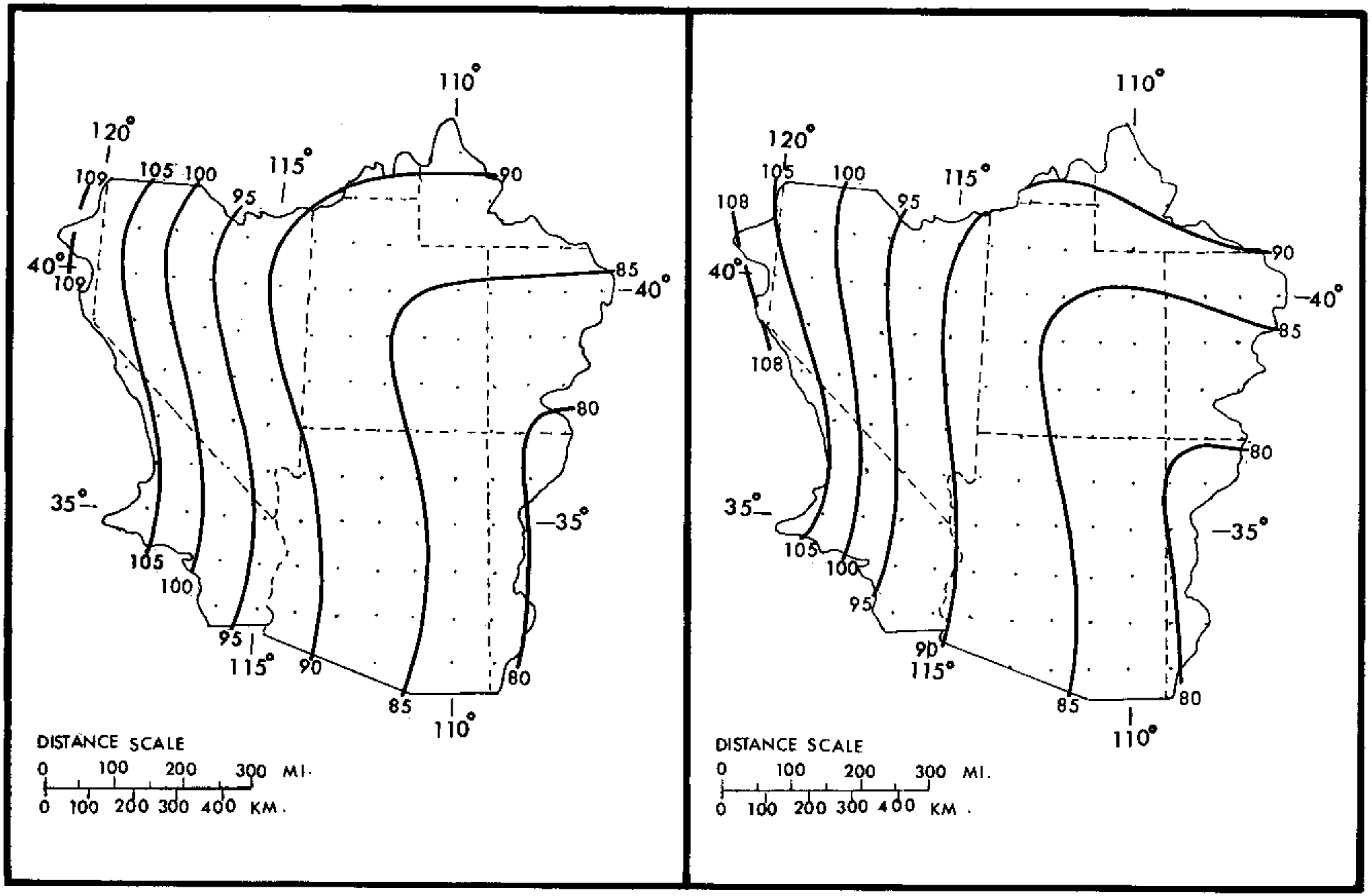
Division of total storm precipitation into two components (convergence and orographic) is uncertain; therefore, direct use of rainfall data to check the seasonal variation of orographic PMP was not attempted. We prefer to evaluate the seasonal variation of <u>total</u> PMP as determined from the criteria developed.

Twenty-four-hr 10-mi^2 (26-km^2) PMP for each month was computed for each point on a 1° grid covering the Southwestern States. The regional pattern of month of maximum is shown in figure 3.18. June gives maximum total PMP for a small portion of the northeast corner of the Southwest. Winter or fall months dominate the northwest portion. The tropical cyclone during August and September dominates three-fourths of the Southwestern States.

In recorded history only a small number of such storms have had important effects on the Southwestern States, mainly Arizona. The storms of September 1939, October 1911, August 1951, and September 1970 were most intense.

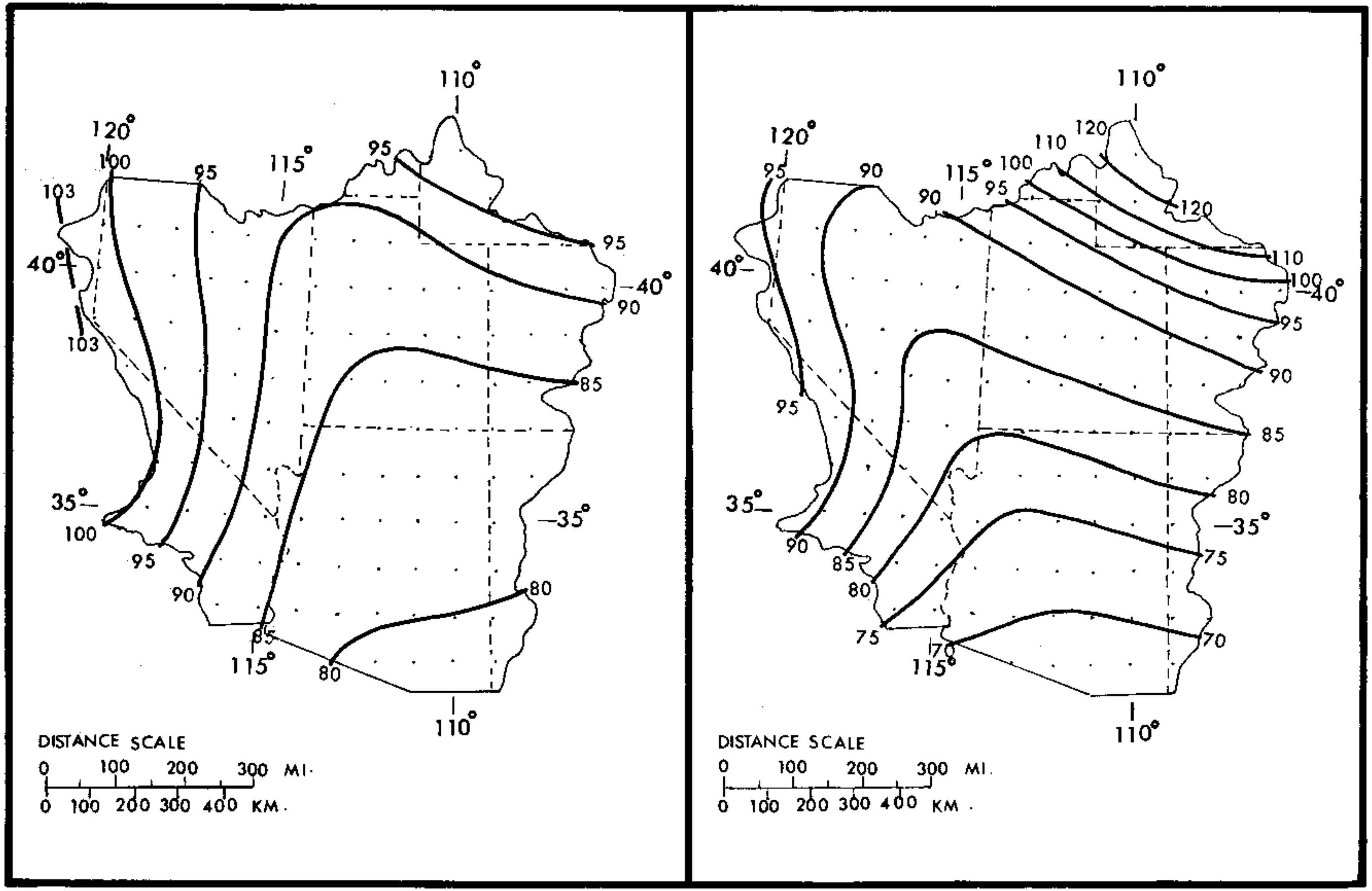
A map was plotted (not shown) that presented a composite of all pertinent tropical storm rainfalls greater than 2.0 inches (51 mm), regardless of duration. A large void in tropical cyclone rainfall existed across most of Nevada eastward to the Wasatch Mountains in Utah. Yet, composite weather maps for some of the tropical storm situations suggest that at some time in the future, only slight changes in synoptic features could bring tropical cyclone-related rainfall into nearly all of Utah and much of Nevada. The infrequency of this storm type means a very long record is needed to delineate the effects of such storms.

Checks were also made from more commonly observed precipitation. One analysis of the month of maximum 24-hr station precipitation in the Western States appears in a study by Pyke (1972). His analysis of these data revealed that much of the Southwest experienced a bimodal distribution of precipitation. Figure 3.19 shows Pyke's results, where the season and



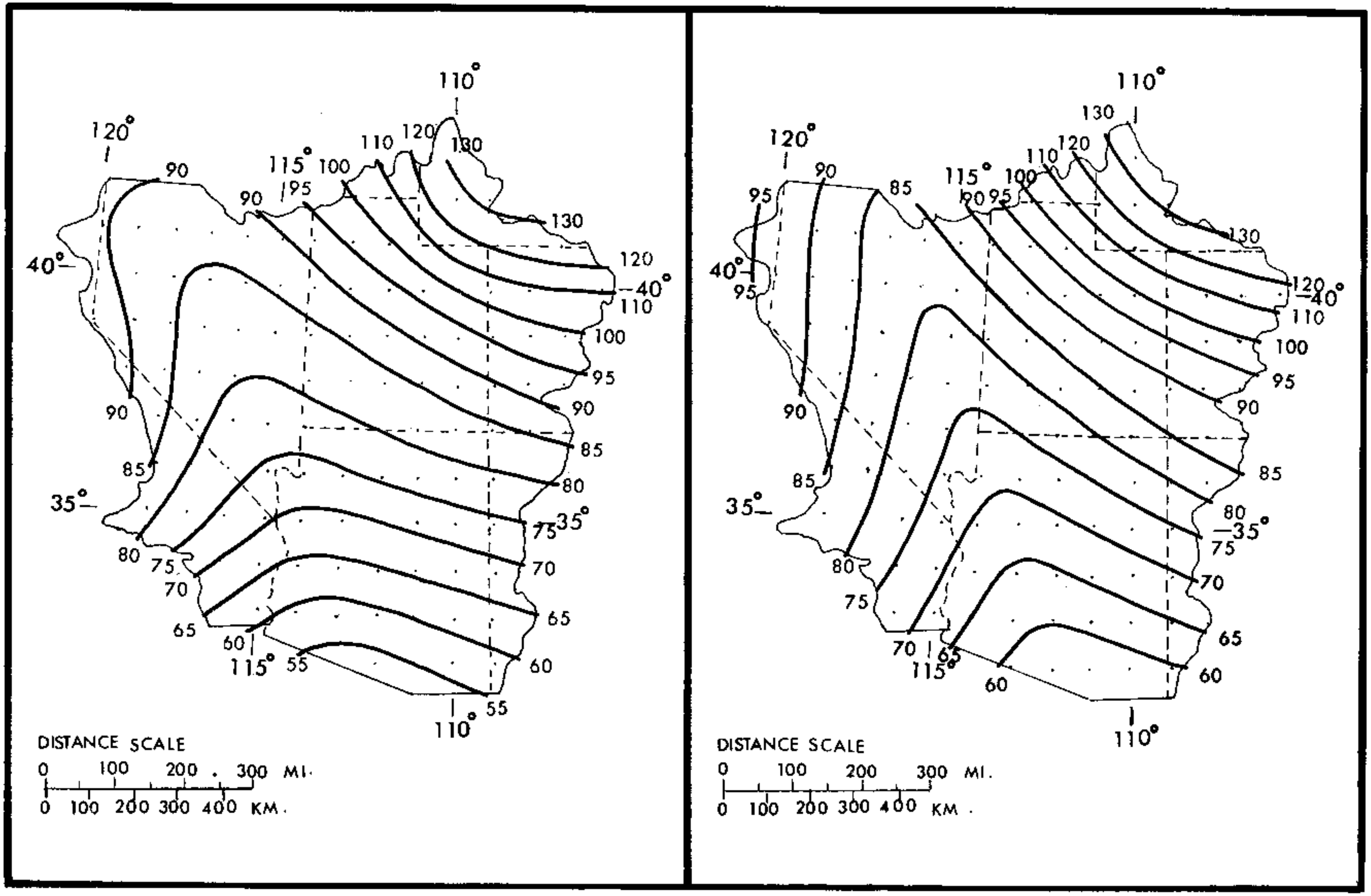
January *February*

Figure 3.12.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).



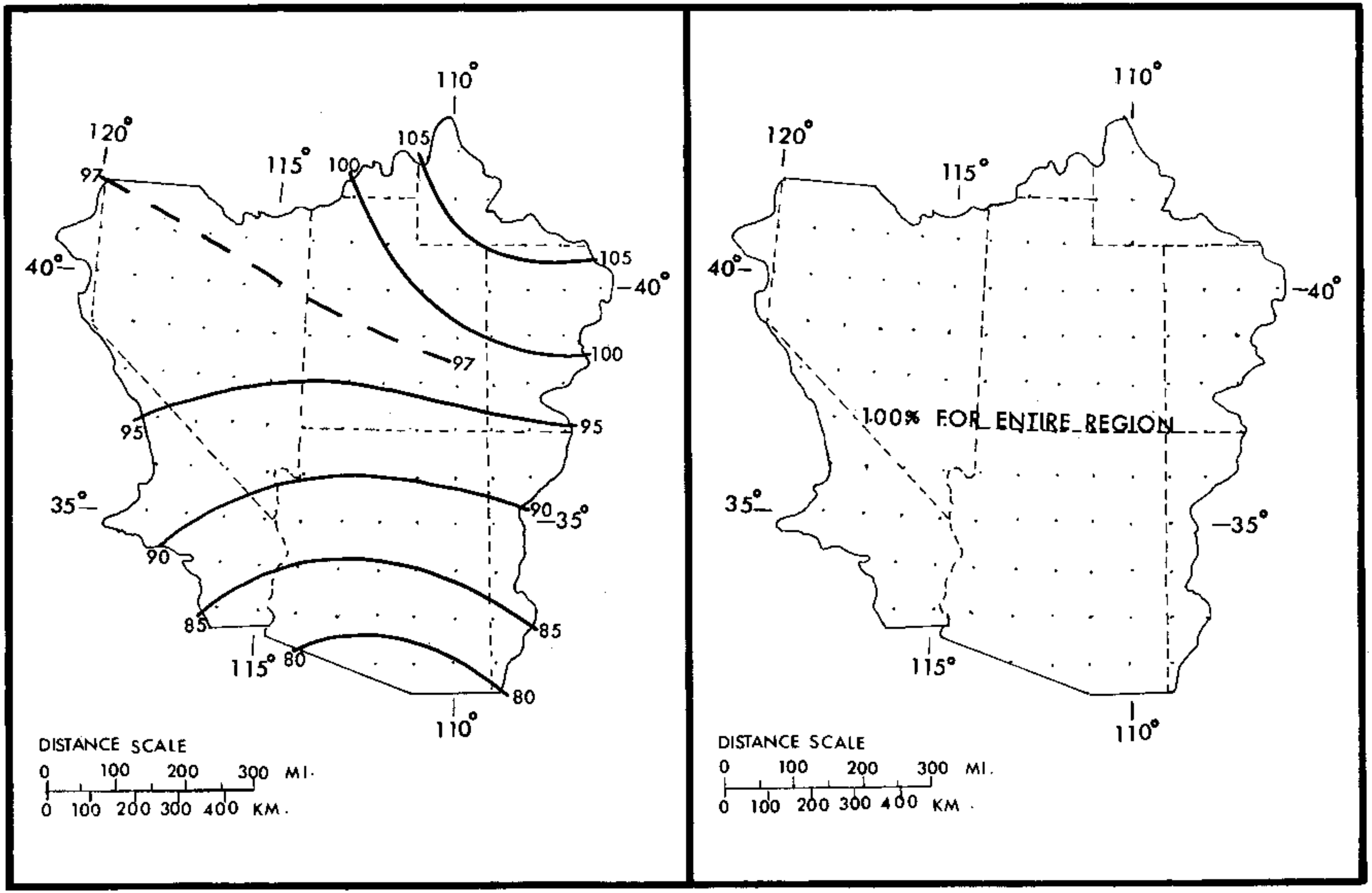
March *April*

Figure 3.13.--Seasonal variation in 10-mi² (26-km²) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).



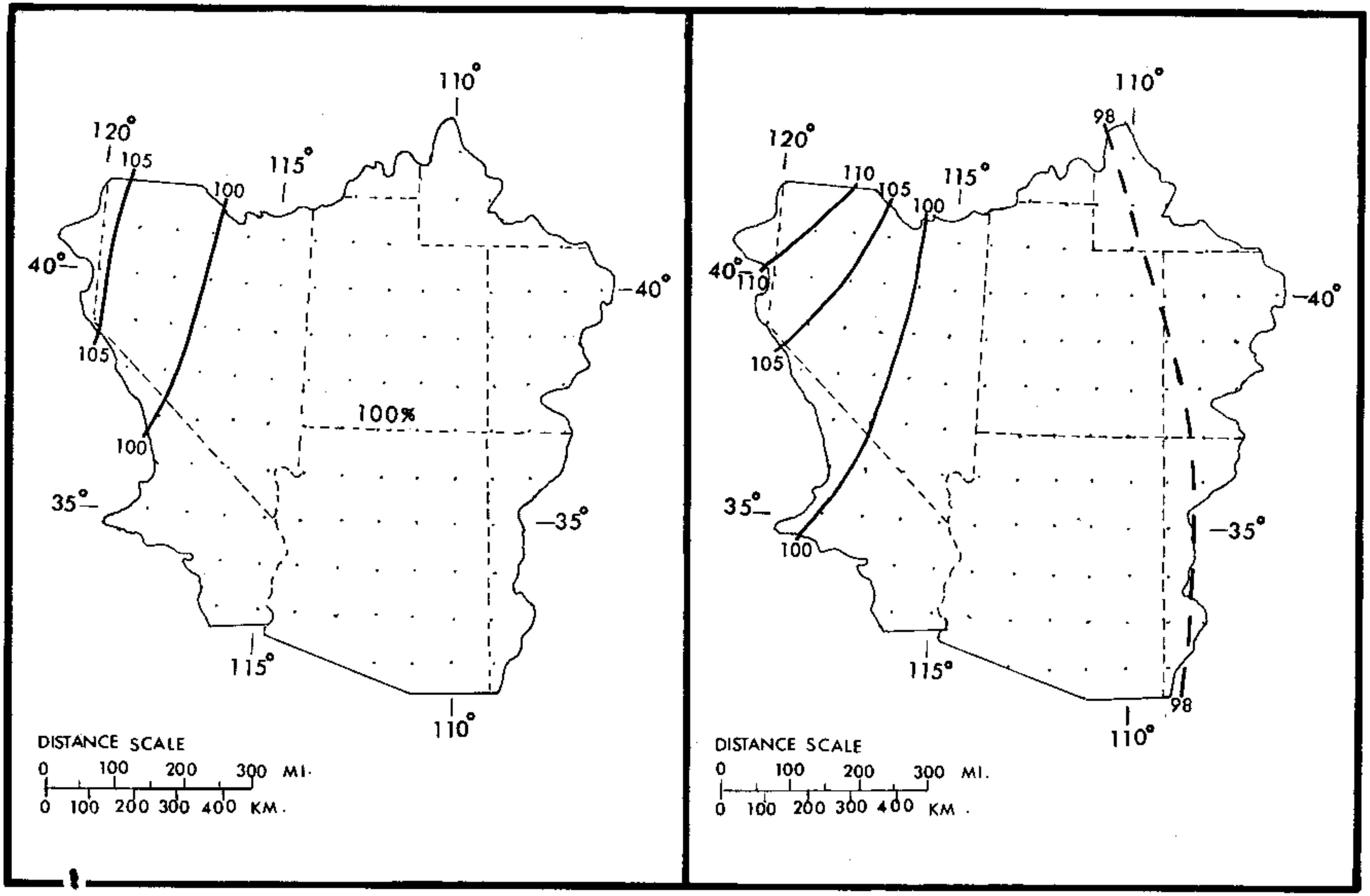
May *June*

Figure 3.14.--Seasonal variation in 10-mi² (26-km²) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).



July *August*

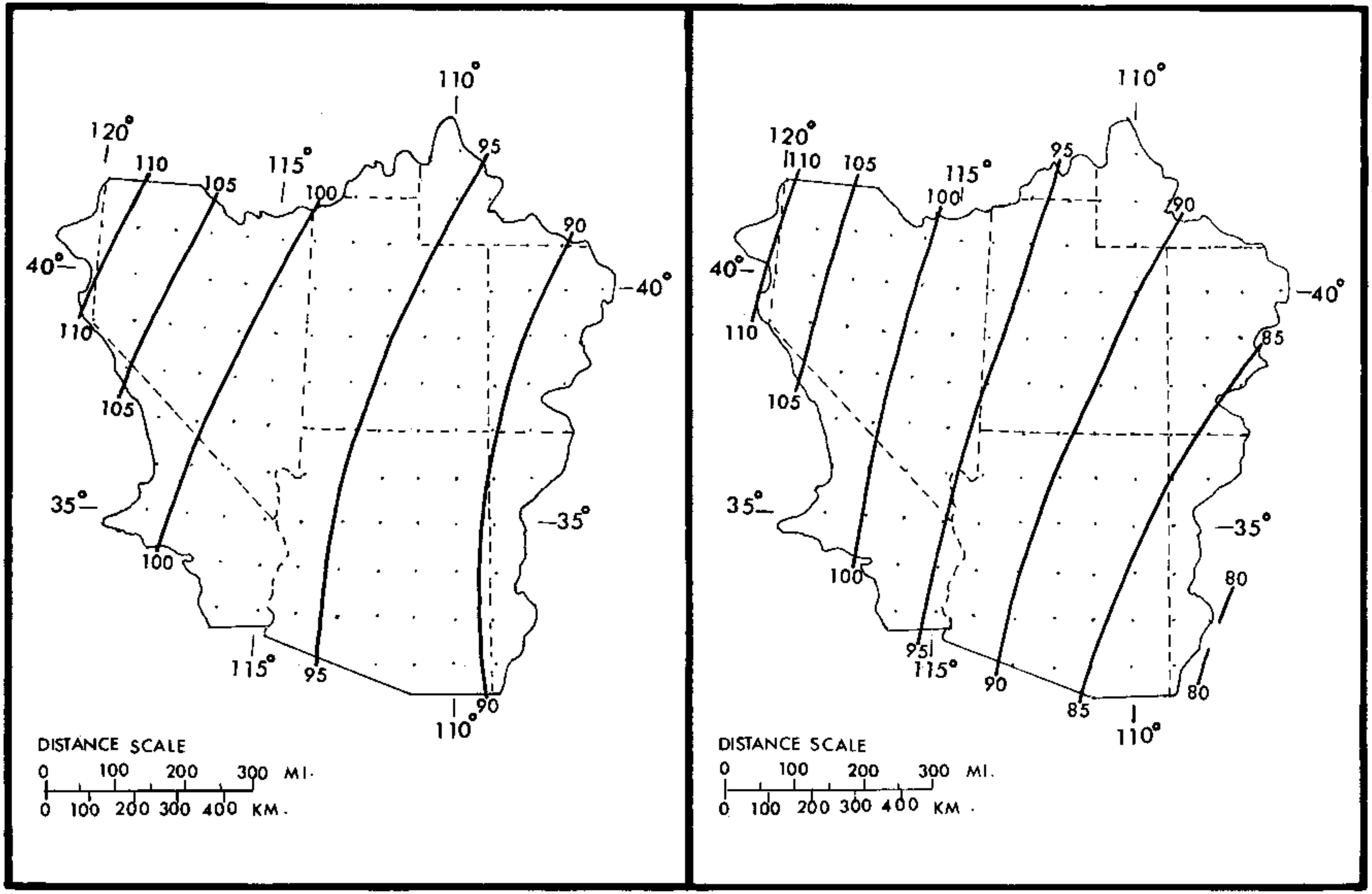
Figure 3.15.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).



September

October

Figure 3.16.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).



November *December*

Figure 3.17.--Seasonal variation in 10-mi² (26-km²) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).

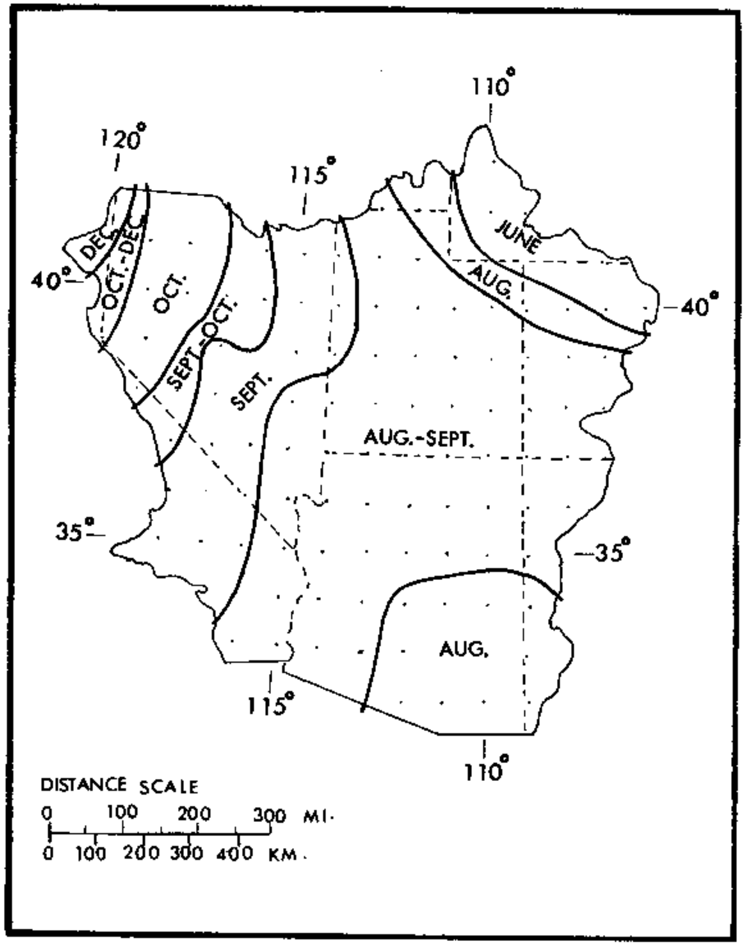


Figure 3.18.--Months of maximum total general-storm PMP for Southwest States, 10 mi^2 (26 km^2) 24 hr.

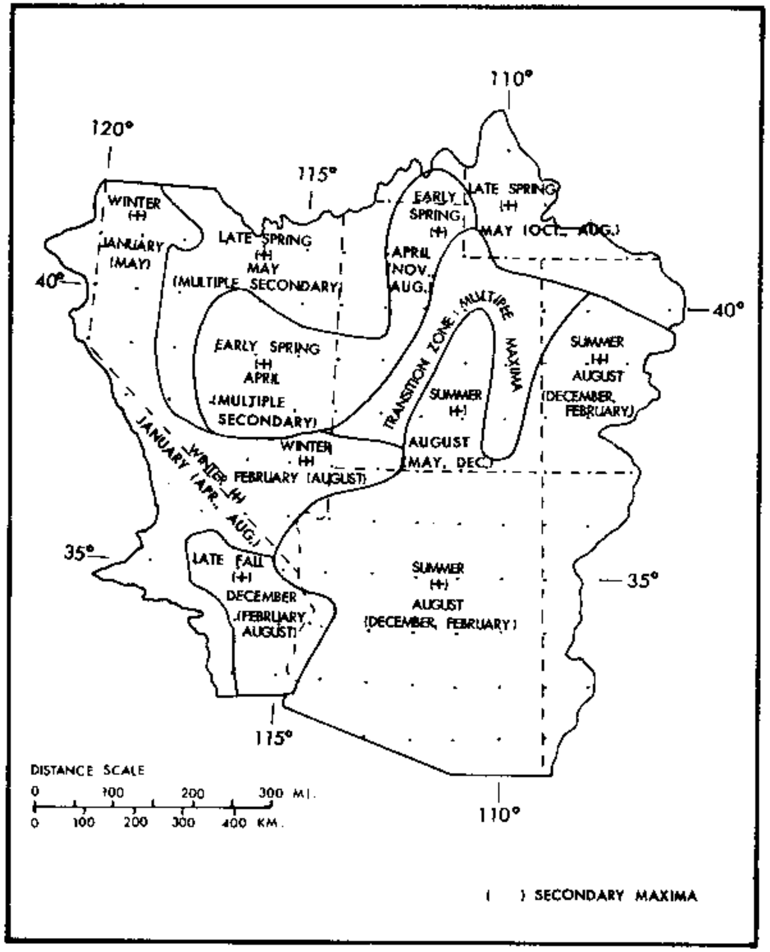


Figure 3.19.--Season and month of maximum and secondary maximum 24-hr station precipitation after Pyke (1972).

month of primary maximum is indicated, and the secondary maximum is given in parenthesis. There is general agreement between month of maximum shown in figure 3.19 and that of this PMP study shown in figure 3.18, particularly considering the need to extend beyond the raw data, which necessarily has in it much bias toward showers. August has a maximum on the southeastern third of the region in Pyke's study and is a secondary maximum through much of the remainder except the northwestern corner. The month of May dominates along the northeast to north-central border of the region, while April appears to dominate in central Nevada to northwestern Utah. The winter maxima of 24-hr precipitation in January and February along the western portion of the Southwest differ from the month of maximum PMP in a similar way. While both areal and point storm rainfall show a winter or spring maximum, the latent possibility of tropical storms, so infrequent in the storm data shifts the PMP to late summer.

An analysis of season of maximum monthly precipitation over the Great Basin was made by Houghton (1969). While monthly precipitation is not a good index to PMP for durations up to 3 days, the comparisons with PMP may be of interest. His conclusions apply to the Great Basin, roughly the northwestern half of the Southwestern States. There is general correspondence between Houghton's results and those of Pyke. The larger expanse of spring maximum in Houghton's work is the major disagreement with the PMP analysis. The seasonal analysis of PMP shown in figure 3.18 is considered justified on the basis of the PMP storm prototypes and the relative potential for precipitation in the various months.

3.4 Variation With Basin Size

3.4.1 Introduction

The orographic PMP index (figures 3.11 a to d) is for the 24-hr duration and a 10-mi^2 (26-km^2) area. For application to specific basins, it is necessary to define a depth-area relation.

Depth-area relations for the orographic PMP index maps are controlled by the steepness, height, length, orientation, and exposure of each slope relative to moisture bearing winds. There is a limit to the lateral extent over which moisture can be transported over mountain slopes without some decrease in intensity. This was assessed for the Sierra Mountains in HMR No. 36 by a study of the variation of pressure gradients with distance between stations that take pressure observations. Figure 3.20 shows this variation by the dashed curve.

An additional factor is required for the present orographic index. This is the way the index was developed. Inflow from several directions was considered in determining the magnitude and gradient of orographic PMP. However, for any particular 6-hr period of the PMP storm over a given drainage, the winds would generally be from one direction and thus have an orographic influence for slopes normal to that direction only.